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Baccalauréat International
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CHEMISTRY
HIGHER LEVEL
PAPER 3

Wednesday 4 November 2009 (morning)

1 hour 15 minutes

Candidate session number

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INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided. You may continue your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet and indicate the number of answer sheets used in the appropriate box on your cover sheet.

0133

Option A — Modern analytical chemistry

A1. ^{1}H NMR and IR spectroscopy both involve the absorption of electromagnetic radiation.

(a) (i) Identify the region of the electromagnetic spectrum used in ^{1}H NMR spectroscopy. *[1]*

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(ii) Explain why tetramethylsilane (TMS) is used as a reference standard in ^{1}H NMR spectroscopy. *[1]*

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(b) Identify which of the following molecules absorbs IR radiation and explain your choice. *[2]*

H_2 O_2 HCl

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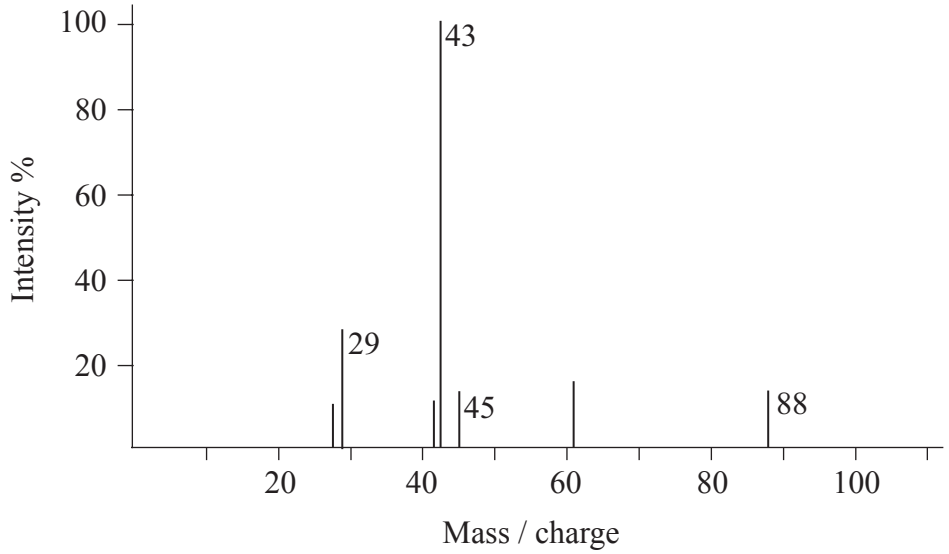
A2. (a) The mass spectrum of an unknown compound, **X**, of empirical formula C_2H_4O is shown below.



[Source: Cleapss Guides: L202 Spectra (Cleapss School Science Service), Sept 2000.]

(i) Determine the relative molecular mass of **X** from the mass spectrum and deduce the formula of the molecular ion. *[2]*

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(ii) Identify a fragment which gives rise to the peak at $m/z = 29$. *[1]*

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(iii) Comment on the absence of a peak at $m/z = 59$. *[1]*

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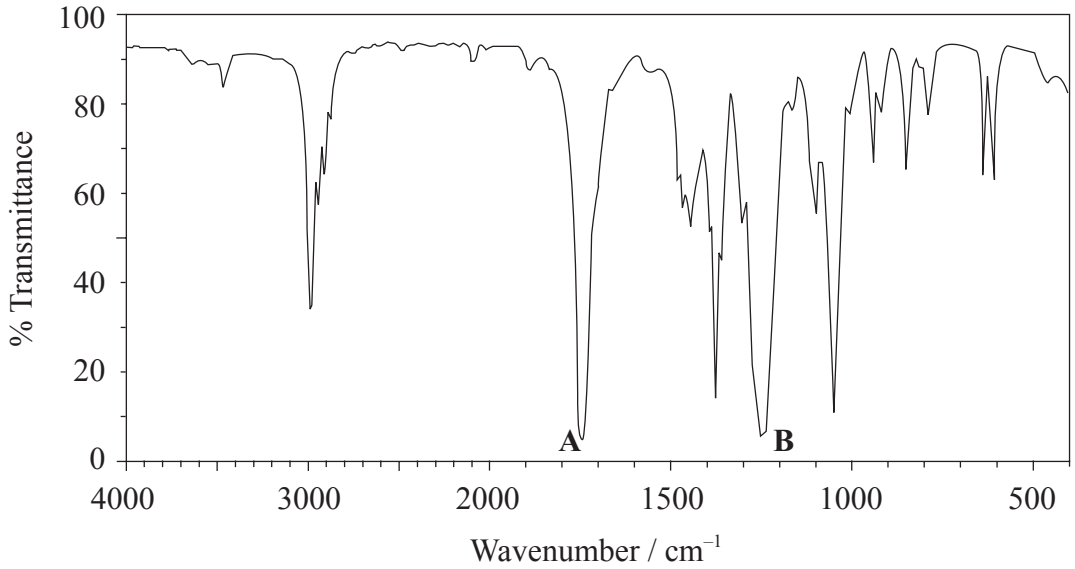
(This question continues on the following page)

(Question A2 continued)

(b) The IR spectrum of **X** is shown below.



[Source: http://modbo1.ibase.go.jp/sdbs/cgi-bin/cre_index.cgi?lang=eng]

(i) Use Table 17 of the Data Booklet to identify the bonds which correspond to the absorptions **A** and **B**. *[1]*

A: . . . . . .

B: . . . . . .

(ii) Deduce the name of the functional group present in **X**. *[1]*

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(This question continues on the following page)

(Question A2 continued)

(c) Typical proton chemical shift values are given in Table 18 of the Data Booklet. The ^{1}H NMR spectrum of **X** contains three peaks. Details of two of these are shown in the table below.

Peak	Chemical shift / ppm	Relative peak area	Splitting pattern
First	2.0	3	Singlet
Second	4.1	2	Quartet
Third			

(i) Deduce a possible structure for **X** that is consistent with the mass, IR and ^{1}H NMR spectra. *[1]*

(ii) Complete the table above by suggesting the chemical shift of the third peak, and state its relative peak area and splitting pattern. *[3]*

(iii) Explain the splitting pattern of the peak at chemical shift **4.1** ppm. *[2]*

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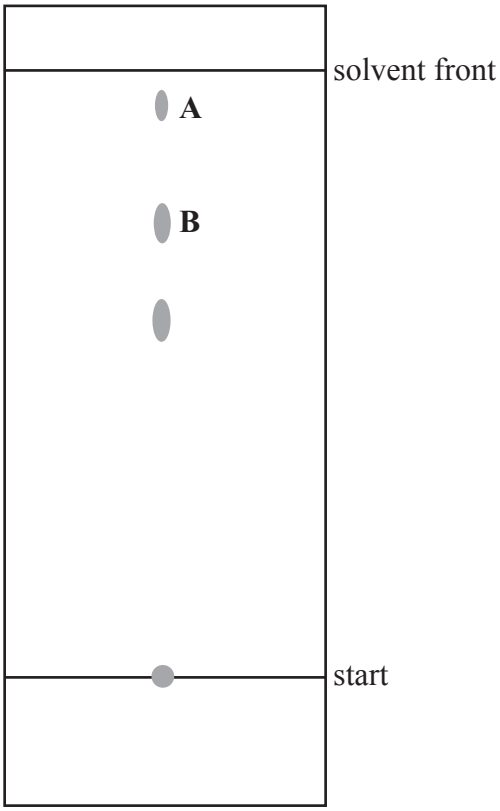
A3. Chromatography is used to test for the presence of illegal drugs in sport.

(a) A chromatogram of a concentrated urine sample from an athlete shows the presence of a banned substance known to have an R_f value of 0.75.

(i) Calculate the R_f values for **A** and **B**, and so deduce which of the spots corresponds to the banned substance. *[2]*



R_f of **A**:

. . . . . .

R_f of **B**:

. . . . . .

Banned substance:

. . . . . .

(ii) Suggest how the results could change if the experiment was repeated with a different solvent. *[1]*

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(This question continues on the following page)

(Question A3 continued)

(b) Paper and column chromatography both have stationary and mobile phases. Identify the stationary phases in the different techniques. *[2]*

Paper chromatography:

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Column chromatography:

. . . . . .

A4. The complex ion $[Ni(H_2O)_6]^{2+}$ is green and $[Ni(NH_3)_6]^{2+}$ is blue. Explain why the $[Ni(H_2O)_6]^{2+}$ complex ion is coloured and outline why changing the identity of the ligand changes the colour of the ion. *[4]*

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Option B — Human biochemistry

B1. Proteins are vital components of living systems.

(a) State the general formula of 2-amino acids. *[1]*

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(b) State **two** characteristic properties of 2-amino acids. *[2]*

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(c) Using Table 19 of the Data Booklet, deduce the structural formula of **two** dipeptides that could be formed by the reaction of alanine with serine and state the other product of the reaction. *[3]*

Other product of the reaction:

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(d) Explain the difference between the primary and secondary structure of proteins. *[2]*

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(This question continues on the following page)

(Question B1 continued)

(e) Explain how a sample of a protein can be analysed by electrophoresis. *[5]*

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B2. Enzymes are proteins which play an important role in the biochemical processes occurring in the body.

(a) State the major function of enzymes in the human body. *[1]*

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(b) Describe the mechanism of enzyme action in terms of structure. *[3]*

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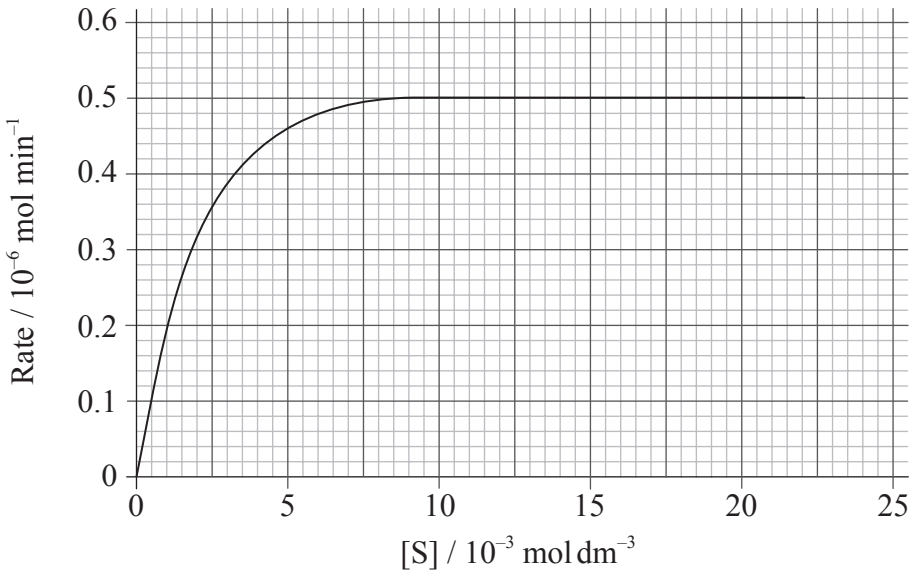
(c) The graph below shows how the rate of an enzyme-catalysed reaction changes as the substrate concentration is increased.

(i) Use the graph to determine V_{max} and the Michaelis constant, K_m. *[2]*



V_{max}: . . . . . .

K_m: . . . . . .

(ii) Draw a line on the graph to represent the effect of adding a competitive inhibitor. *[1]*

(This question continues on the following page)

(Question B2 continued)

(d) State and explain the effects of heavy-metal ions and temperature increases on enzyme activity. *[5]*

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Option C — Chemistry in industry and technology

C1. (a) Aluminium is extracted by the electrolysis of a molten mixture containing alumina, Al_2O_3, using graphite electrodes.

(i) State a half-equation for the reaction at the negative electrode (cathode). *[1]*

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(ii) Oxygen is produced at the positive electrode (anode). State the name of another gas produced at this electrode. *[1]*

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(b) (i) State **two** properties of aluminium that make it suitable for use as an overhead electric cable. *[1]*

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(ii) Alloys of aluminium with nickel are used to make engine parts. Explain, by referring to the structure of these alloys, why they are less malleable than pure aluminium. *[2]*

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C2. Polyvinyl chloride (PVC) and polyethene are both polymers made from crude oil.

(a) Explain why PVC is less flexible than polyethene. *[2]*

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(b) State how PVC can be made more flexible during its manufacture and explain the increase in flexibility on a molecular level. *[2]*

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(c) PVC can exist in isotactic and atactic forms. Draw the structure of the isotactic form showing a chain of at least six carbon atoms. *[1]*

C3. Nano-sized '*test-tubes*' with one open end, can be formed from carbon structures.

(a) Describe these '*test-tubes*' with reference to the structures of carbon allotropes. *[2]*

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(b) Carbon nanotubes can be used as catalysts.

(i) Suggest **two** reasons why they are effective heterogeneous catalysts. *[2]*

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(ii) State **one** potential concern associated with the use of carbon nanotubes. *[1]*

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C4. Rechargeable nickel-cadmium batteries are used in portable electrical equipment and emergency lighting.

The **discharge** process can be summarized by the equation below.

$$2NiO(OH)(s) + Cd(s) + 2H_2O(l) \rightleftharpoons 2Ni(OH)_2(s) + Cd(OH)_2(s)$$

(a) State the change in oxidation number of the cadmium and deduce if it is acting as the positive or negative electrode during the discharge process. *[2]*

. . . . . .

. . . . . .

(b) Identify a physical property of $Cd(OH)_2$ which allows this process to be reversed and the battery recharged. *[1]*

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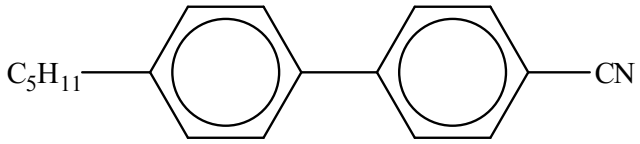
C5. The structure of 4-pentyl-4-cyanobiphenyl, a commercially available nematic crystalline material used in electrical display devices, is shown below.



(a) Explain how the three different parts of the molecule contribute to the properties of the compound used in electrical display devices. *[3]*

CN:

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C_5H_{11}:

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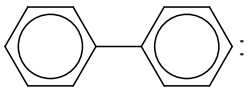
:

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(b) Describe and explain in molecular terms the workings of a twisted nematic liquid crystal. *[4]*

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Option D — Medicines and drugs

D1. The discovery of penicillin was one of the most significant scientific discoveries of the last century.

(a) Describe the mode of action of penicillins in treating infectious diseases. *[2]*

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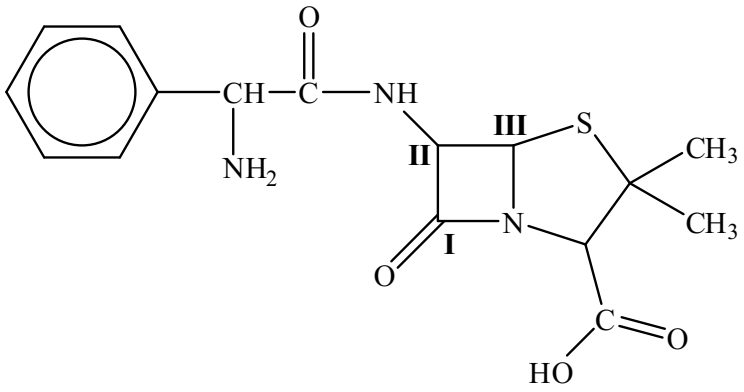
(b) Ampicillin is a semi-synthetic penicillin used to treat lung infections. The structure of the antibiotic is shown below.



(i) Explain why it is important to continue to develop semi-synthetic penicillins. *[2]*

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(ii) Describe how computers are used in drug design. *[2]*

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(This question continues on the following page)

(Question D1 continued)

(c) State the type of hybridization of each of the carbon atoms (**I**, **II**, and **III**) in the β-lactam ring of ampicillin by completing the table below, and explain why the amide group is highly reactive. *[2]*

Carbon atom	**I**	**II**	**III**
Hybridization			

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D2. (a) Explain the meaning of the terms:

(i) *side-effect* *[1]*

. . . . . .

. . . . . .

(ii) *therapeutic window* *[1]*

. . . . . .

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(iii) *placebo effect.* *[1]*

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(b) The effectiveness of a drug depends on the method of administration.

(i) One method of injecting drugs into the body results in the drug having a very rapid effect. State the method and explain its rapid action. *[2]*

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(ii) List the **two** other methods which can be used to inject drugs into the body. *[1]*

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(iii) Identify the method of administration used to treat respiratory diseases such as asthma. *[1]*

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D3. Amphetamine and methamphetamine are widely abused drugs.

(a) State **one** short-term effect of amphetamine on the human body. *[1]*

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(b) Explain why amphetamine is classified as a *sympathomimetic drug* and relate this to its structure. *[2]*

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(c) Regular use of amphetamine and methamphetamine can lead to *tolerance*. Explain why this is potentially dangerous. *[2]*

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(d) Amphetamine exists as optical isomers. Describe how chiral auxiliaries can be used to synthesize only the desired enantiomeric form of a drug from a non-chiral starting compound. *[3]*

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(e) The structures of morphine and heroin are shown in Table 20 of the Data Booklet. Explain the increased potency of heroin compared to morphine. *[2]*

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Option E — Environmental chemistry

E1. It is now widely accepted that the increased production of carbon dioxide is leading to global warming.

(a) Describe how carbon dioxide acts as a greenhouse gas. *[2]*

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(b) Discuss the influence of increasing amounts of greenhouse gases on the environment. *[3]*

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E2. The biochemical oxygen demand (BOD) is a measure of water pollution.

(a) Identify the stage of sewage treatment which removes the substances responsible for high BOD values and explain how this is done. *[2]*

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(b) Describe how the addition of nitrates or phosphates to water can increase the BOD value of a water sample. *[2]*

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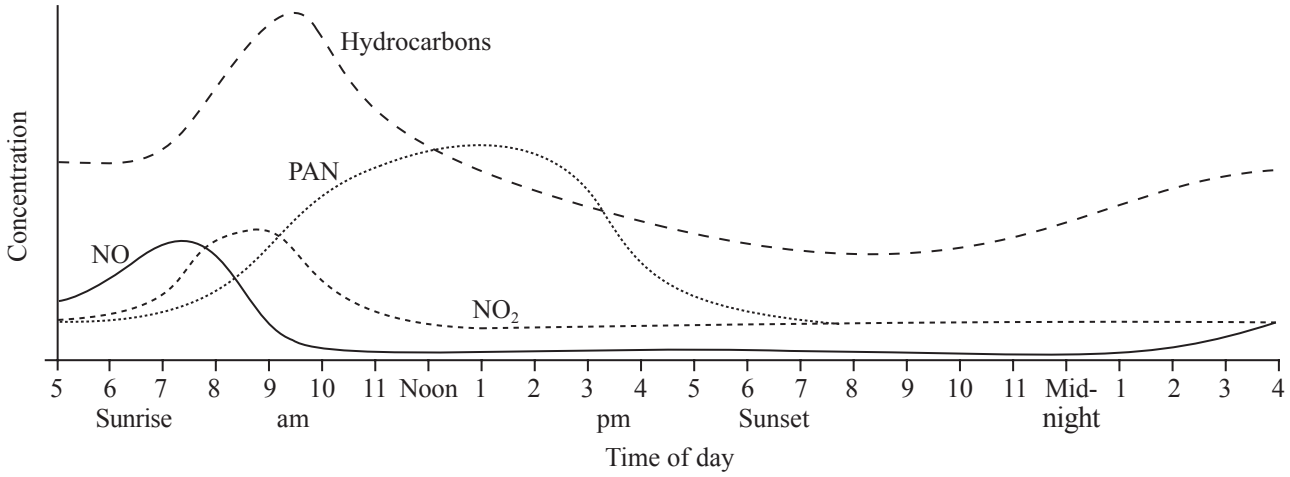
E3. The concentration of some pollutants in a city was measured over a 24 hour period. The results are shown below.



(a) Outline the cause of the increase in NO levels between 5 and 8 am. *[2]*

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(b) Outline the cause of the increase in concentration of peroxyacylnitrates (PANs) between 8 am and 2 pm. *[2]*

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(c) State why a temperature inversion often results in the formation of smog. *[1]*

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(d) Show, by stating an equation, how **one** of the above pollutants reacts with HO• radicals to produce a constituent of acid rain. *[1]*

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E4. Landfill sites are used to dispose of about 90 % of the world's domestic waste, but incineration is being increasingly used in some countries.

(a) State **one** advantage of each method. *[2]*

Landfill:

. . . . . .

. . . . . .

Incineration:

. . . . . .

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(b) Suggest why some biodegradable plastics do not decompose in landfill sites. *[1]*

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(c) High-level and low-level wastes are two types of radioactive waste. Compare the half-lives and the methods of disposal of the two types of waste. *[3]*

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E5. Compounds of heavy metals are one type of toxic substance found in water. Lead(II) ions, Pb^{2+}, can be removed by bubbling hydrogen sulfide, H_2S, through polluted water. The solubility product of lead sulfide is $1.25 \times 10^{-28}\,mol^2\,dm^{-6}$ at 25°C.

(a) Calculate the concentration of Pb^{2+} ions in a saturated solution of lead sulfide. *[2]*

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(b) Explain how the addition of hydrogen sulfide decreases the concentration of Pb^{2+} ions in a saturated solution. *[2]*

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Option F — Food chemistry

F1. Malnutrition can be caused by starvation, dieting or a person eating an excess of highly processed food.

(a) State **one** function of a nutrient. *[1]*

. . . . . .

. . . . . .

(b) Describe the structural composition of the following nutrients:

(i) fats and oils *[2]*

. . . . . .

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(ii) monosaccharides. *[2]*

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(c) Liver is a source of arachidonic acid, $CH_3(CH_2)_4(CH{=}CHCH_2)_4(CH_2)_2COOH$, and fish oils are a source of linolenic acid. With reference to the structure of linolenic acid in Table 22 of the Data Booklet, explain why arachidonic acid has a much lower melting point compared to linolenic acid, even though it contains two more carbon atoms. *[3]*

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F2. Antioxidants can be used to prolong the shelf life of food.

(a) Define the terms:

(i) *shelf life* *[1]*

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. . . . . .

(ii) *antioxidant.* *[1]*

. . . . . .

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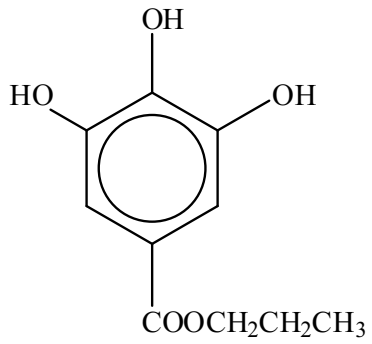
(b) Using Table 22 of the Data Booklet, and the structure of propyl gallate (PG) below, compare the structural features of the three common antioxidants 3-BHA, BHT and PG. *[4]*



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(This question continues on the following page)

(Question F2 continued)

(c) State **one** example of a common naturally occurring antioxidant and state **one** possible long-term health benefit of consuming food in which it is present. *[2]*

Antioxidant:

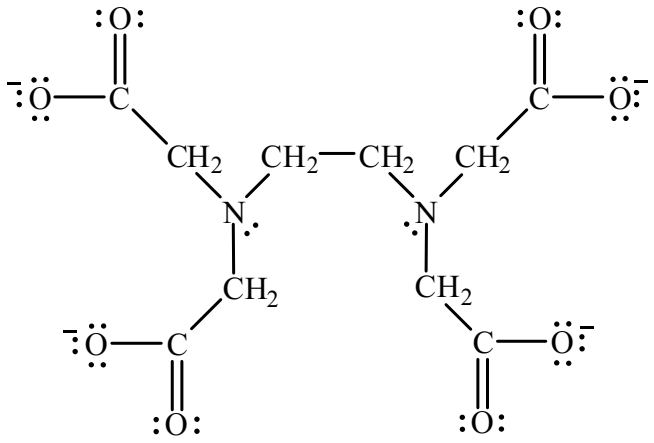
. . . . . .

Long-term health benefit:

. . . . . .

. . . . . .

(d) $(EDTA)^{4-}$, the ethylenediaminetetraacetate anion, is a chelate ligand with the following structure.



It has been found to inhibit the Fe^{2+} catalysed oxidation of raw beef. Explain why $(EDTA)^{4-}$ can be described as a chelate ligand. *[1]*

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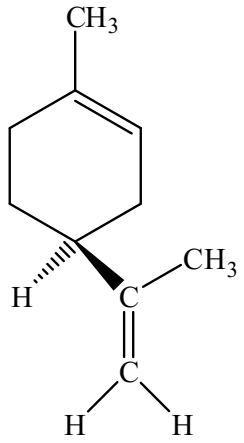
F3. Different conventions are used to classify enantiomers. Orange and lemon peel each contain different enantiomers of the compound limonene. One of the enantiomers is represented below.



(a) Identify the chiral centre in this enantiomer with an asterisk, *. *[1]*

(b) The (+)*d*-enantiomer has the characteristic smell of oranges and the (–)*l*-enantiomer has the characteristic smell of lemons. Explain the meaning of the (+)*d* and (–)*l* symbols used in this notation. *[1]*

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(c) The R, S notation is also used. The (+)*d*-enantiomer is often described as R-limonene and the (–)*l*-enantiomer as S-limonene. Explain what is meant by the R, S notation and state whether the structure shown is R or S. *[2]*

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F4. The chemical process that makes butter rancid is called oxidative rancidity. Describe, using equations, the steps involved in the free-radical chain mechanism that occurs during oxidative rancidity. *[4]*

Initiation:

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Propagation:

. . . . . .

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Termination:

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Option G — Further organic chemistry

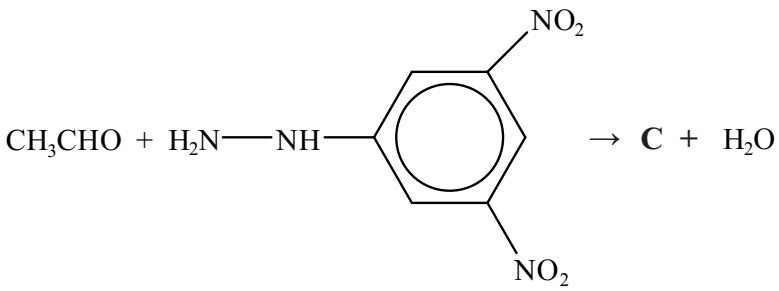
G1. The carbonyl chemistry of both aldehydes and ketones involves a number of different types of reactions.

(a) State the formulas of the products, **A**–**C**, formed in the following reactions.

(i) $(CH_3)_2CO \xrightarrow[H_2O]{CH_3CH_2MgBr} \mathbf{A} + \mathbf{B}$ *[2]*

A: . . . . . .

B: . . . . . .

(ii) 

[1]

C: . . . . . .

(b) State the type of reaction involved in the formation of **C** and H_2O in (a) (ii). *[1]*

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G2. Ethanoic acid and chloroethanoic acid both contain the carboxyl group.

(a) Explain why chloroethanoic acid is a stronger acid than ethanoic acid. *[2]*

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(b) Starting with chloromethane, outline **one** possible reaction pathway to synthesize ethanoic acid. Your answer should include:

- the reagents used
- a relevant chemical equation for each step. *[2]*

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G3. (a) Alkenes commonly react by electrophilic addition reactions. Describe the mechanism of the following reaction, using curly arrows to show the movement of electron pairs, and suggest the reason for the formation of the major organic product, **D**. *[5]*

$$CH_2{=}CH(CH_2CH_3) + HI \rightarrow \mathbf{D}$$

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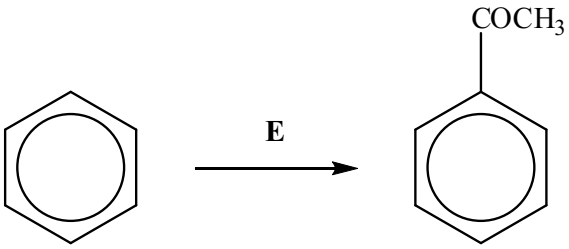
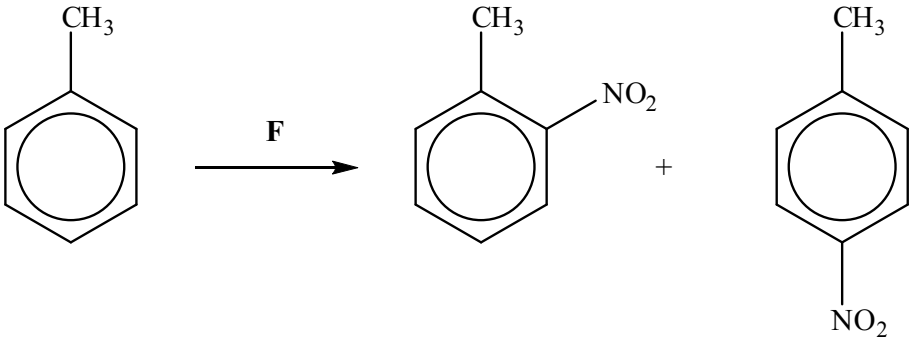
(This question continues on the following page)

(Question G3 continued)

(b) Both benzene and methylbenzene undergo electrophilic substitution reactions. State the formulas of the reagents, **E**–**G**, **including any catalysts used**, in the following conversions. *[3]*



E: . . . . . .



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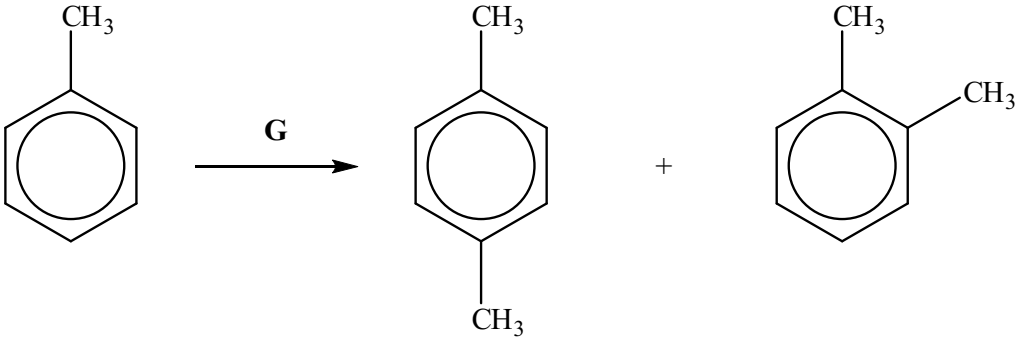

G: . . . . . .

(This question continues on the following page)

(Question G3 continued)

(c) State the formulas of the products **H** and **I**, formed in the following reaction. *[2]*

$$C_6H_5CH_2Br + NaOH \rightarrow \mathbf{H} + \mathbf{I}$$

H: . . . . . .

I: . . . . . .

(d) (i) State whether –OH can be described as an activating or deactivating group with respect to aromatic electrophilic substitution reactions. *[1]*

. . . . . .

(ii) Describe the directing effect of –OH on a benzene ring in an aromatic electrophilic substitution reaction. *[1]*

. . . . . .

(iii) Explain the decreased reactivity due to the presence of the $–NO_2$ group in an aromatic electrophilic substitution reaction. *[2]*

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(e) Consider the two amines methylamine, CH_3NH_2, and dimethylamine, $(CH_3)_2NH$.

(i) Using Table 15 of the Data Booklet, state which of the amines is the more basic. *[1]*

. . . . . .

(ii) Explain the relative basicities of the two amines. *[2]*

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